DEVELOPMENT AND CORRECTION OF HYPERNATREMIA DURING A TWO HOUR HIKE AT THE HIGHEST TEMPERATURE IN THE SODOM REGION
(A Preliminary Report)

NASA TT F-9716

M. Toor, E. Wertheimer, S. Massry, and J. B. Rosenfeld

N66-11618

(ACCESSION NUMBER) 15 (PAGES) (NASA CR OR TMX OR AD NUMBER)

(THRU) 1 (CODE) 04 (CATEGORY)

FACILITY FORM 602

GPO PRICE $ _____

CFSTI PRICE(S) $ _____

Hard copy (HC) 1.00

Microfiche (MF) .50

ff 653 July 65

Harefuah, Vol. 57, pp. 244-248, 1959.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. NOVEMBER 1965

DEVELOPMENT AND CORRECTION OF HYPERNATREMIA DURING A TWO HOUR HIKE AT THE HIGHEST TEMPERATURE IN THE SODOM REGION
(A Preliminary Report)

HAREFUAH, Jerusalem, 1959

M. Toor, Beillinson Hospital, Petach-Tikvah
E. Wertheimer, Dept. of Biochemistry of the Hebrew University Medical School in Jerusalem
S. Massry, Beillinson Hospital, Petach-Tikvah
J. B. Rosenfeld, Beillinson Hospital, Petach-Tikvah

Considerable research has been undertaken in the area of acclimatization of residents of colder regions to hot regions (5 - 1). Little, however, has been done in the exploration of the influence of climatic conditions on the daily activities of the indigenous population of the hot regions.

One of the projects carried out by our group deals with the results of a two-hour hike during the mid-day heat under the following conditions: 1. without fluid intake 2. with free fluid intake 3. with forced or excessive fluid intake during a march at the speed of six kilometers per hour. The experiments were carried out in the Dead Sea Area near Sodom /See Note/ on eight subjects 18 to 26 years, seven of whom were natives of the Middle East. The experiments took place on 10 July 1957 between 10 - 12 noon at a temperature reading of 42°C.

The eight subjects of the experiments resided at Sodom for a period of six months to two years and underwent a medical examination prior to the hike which revealed no indication of a disease. Prior to the experiment, the subjects were weighed

without clothes and emptied their bladder. Measurements of height, blood pressure, body temperature were also taken. Their A.K.G. and lung functioning were registered and samples of blood and saliva were taken for a laboratory examination.

The subjects wore light clothes during the hike. Their fluid intake differed from group to group. No food was, however, eaten during the hike. At the completion of the hike, the subjects removed their clothes, wiped off perspiration and underwent the same tests as before the hike. The subjects were accompanied on the hike by a physician in a pick-up truck which carried containers of water.

The subjects of the experiment were divided into the following three groups:

1. Three subjects without fluid intake.

2. Three subjects with free fluid intake.

3. Two subjects with forced fluid intake who were given additional quantities of fluid regardless of their sensation of thirst.

The subjects drank water or fruit juices in accordance with their personal preferences. A third of the fluid intake was fruit juices.

The methods of testing

The PH of the blood was examined by the Cambridge instrument with a glass electrode and the result was adjusted to a temperature of 38°C (6); The alkali reserve in accordance with the Van Slyke method or micro method (7); protein quantity (T.P.) in accordance with the Biuret method (8); hemoglobin by the cholorometric method (9); hemaatokrit (HTK) in accordance with the Weintraub method (10); sugar in the blood by the Folin--Wu method (11); creatonin in the blood and urinary excretion by the Folin--Wu method (12); urea in the blood by the Nessler method modified by Rappoport (13); potassium, sodium in the blood and urinary excretion by means of flame photometry (14); chlorine in plasma and urinary excretion by the Schales and Schales method modified by Rappoport (15); urea in urinary excretion by the Kowatsky method modified by Rappoport (13).

/Note/: The Dead Sea is located 395 meters below sea level. The Sodom area has an average temperature of 25°C with an average temperature during the coldest month of 15°C and the hottest month of 35°C. The maximum temperature of the hottest month is 42°C with a low of 27°C. The highest relative humidity

during the winter is 68%. During the summer months between June and August, the relative humidity is between 43% - 50%. The barometric pressure during the summer months is 788 - 789 and in the winter approximately 800 millimeters of mercury. The average wind velocity is 10 kilometers per hour. The maximum wind velocity in summer is 15 - 20 kilometers per hour.

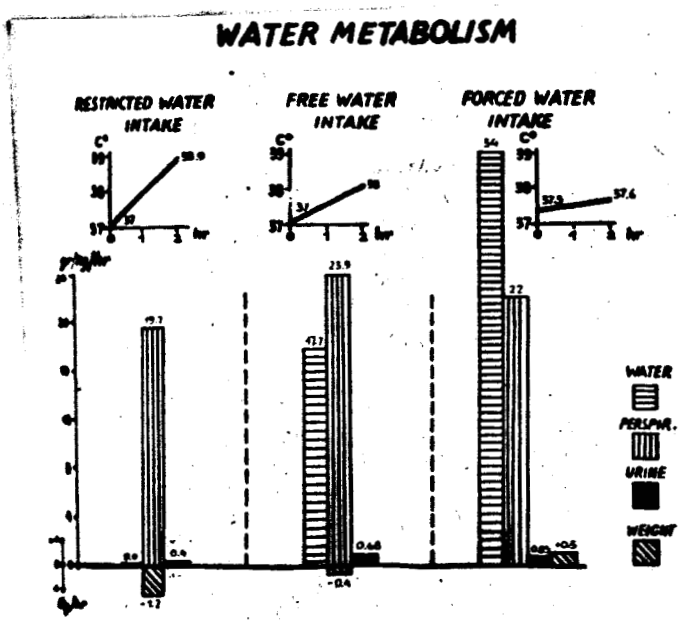
The results

Table 1: The nutritional state of the subjects

Name	Height(centimeters)	Weight (kilograms)	Blood pressure
A.A.	170	58,400	105/70
Sh.Y.	166	58,300	130/90
M.Y.	176	71.200	115/75
K.A.	168	64.	100/60
A.H.	161	55.700	115/65
F.A.	173	75.	135/80
V.A.	171	64.	120/70
A.Z.	172	54.	110/75

Table one shows that the ratio of weight to height of the subjects, that the nutritional state of all the subjects with the exception of one was somewhat below normal. After the experiment, the subjects of group one showed signs of extreme restlessness and complained about dryness in the mouth and extreme fatigue. The subjects of the third group, however, showed no indications of the symptoms of group one and complained only of tiredness.

Water metabolism and body temperature (diagram 1)



The subjects without fluid intake excreted only 55 millimeters of urine in the course of two hours. Their weight dropped by an average of 2.360 kilograms, while their normal body temperature rose by two degrees in two hours. Those who drank at will consumed approximately 3,260 millimeters of fluid and execreted 95 millimeters of urine. They also lost 1.500 kilograms in weight and their body temperature rose by only one degree. The members of the group with forced water intake drank approximately 3,960 millimeters of fluid, excreted 50 millimeters of urine, put on one kilogram in weight, while their body temperature remained stable. The perspiration of the subjects with no water intake was somewhat lower, and they experienced a rise in temperature.

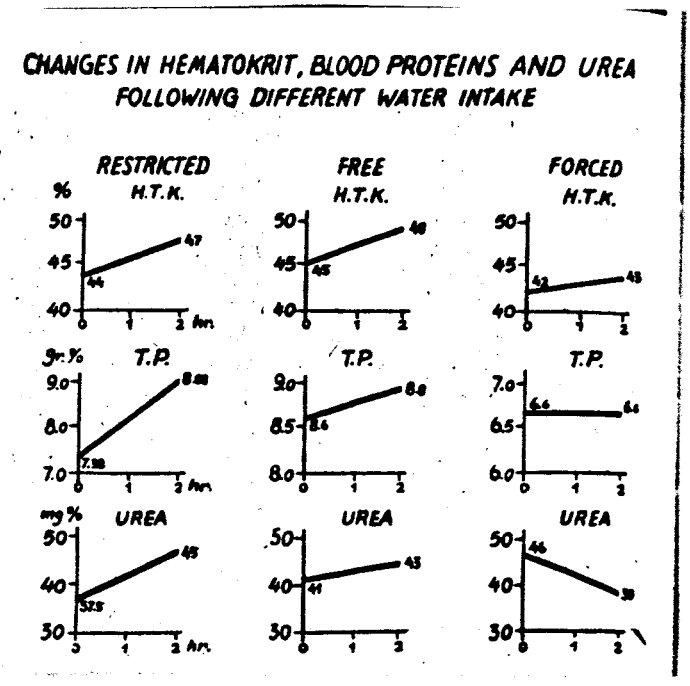


Diagram 2

The hematokrit and blood proteins (diagram 2) in the group without water intake increased while the blood pressure remained stable.

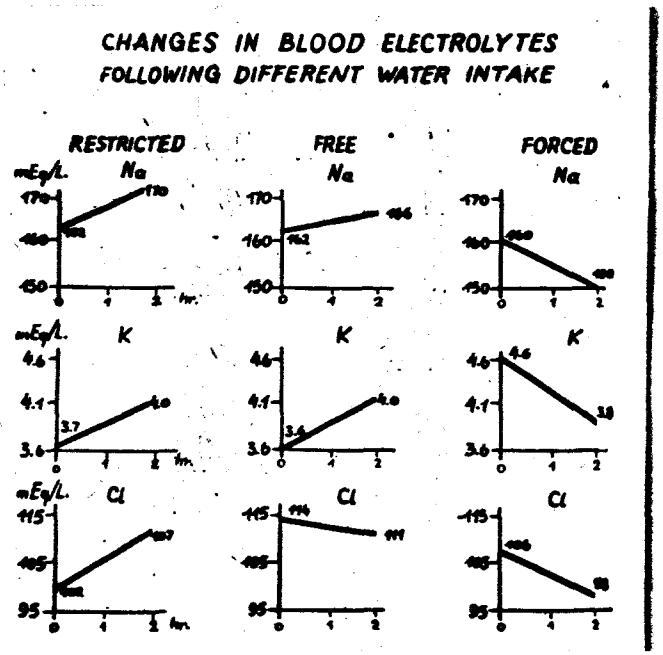


Diagram 3

Sodium (diagram 3). The average sodium content in the plasma of the subjects exceeded the 150 m Eq/L even before the hike. After the hike, the highest excess of sodium in the blood was found among the subjects with no fluid intake. At the same time, in the subjects with forced fluid intake, the average sodium content declined by 10 m Eq/L notwithstanding the exertion of the hike and returned to the normal level.

Chlorine (diagram 3). The changes in the chlorine level of the blood were not as marked as the changes in the sodium content, although the general pattern of change was similar to the changes in the sodium content.

Potassium (diagram 3). At the beginning of the experiments, the average potassium content among the subjects without fluid intake was below normal and increased somewhat after the hike. The potassium content decreased after the hike among the subjects with forced fluid intake.

CHANGES IN BLOOD pH AND ALKALI RESERVE
FOLLOWING DIFFERENT WATER INTAKE

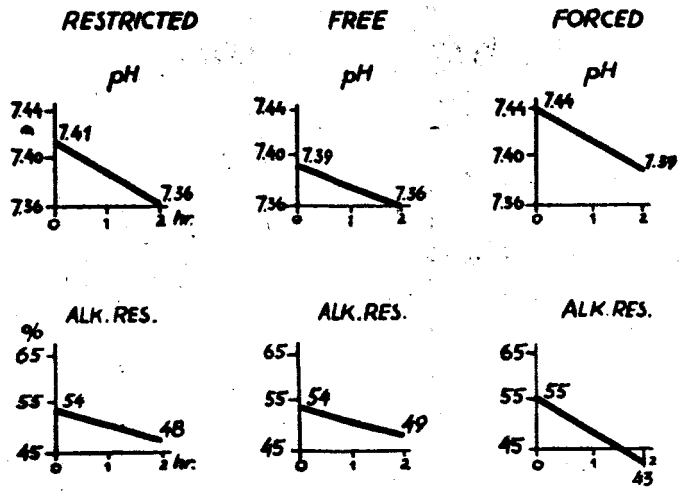


Diagram 4

PH (diagram 4). In spite of the increased hypernatremia experienced after the hike by the subjects without fluid intake and the group with free fluid intake, the PH showed tendencies to decrease. The smallest decrease, however, was registered among the group with forced fluid intake.

Alkali reserve (diagram 4). The alkali reserve remained stable in all the three groups. There was no change among the subjects without fluid intake, although a decrease in the alkali reserve was registered among the subjects with forced fluid intake.

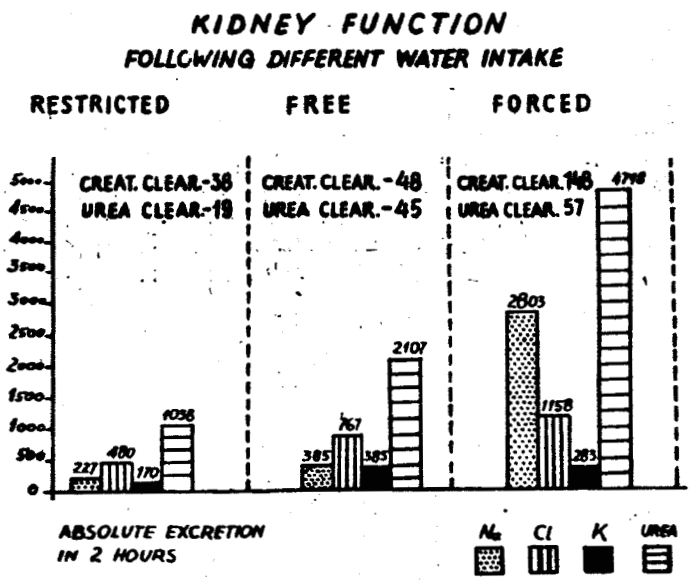


Diagram 5

Clearance of urea (diagram 5). The process of urea clearance followed the pattern of change observed in the clearance of createnin. The process of urea clearance was accelerated among the subjects with forced fluid intake.

The excretion of urea among the subjects who drank at will was five times larger than among the subjects without fluid intake.

The sodium excretion in the urine (diagram 5) was the lowest among the group without water intake in spite of the fact that the members of this group had the highest sodium content in the blood. The sodium excretion in the urine rose with increased drinking. At the same time, however, a decrease in the sodium content of the blood was evidenced.

The quantity of chlorine excretion in the urine among the subjects without water intake was found to be twice as large as the quantity of the sodium excretions. The subjects who drank at will had a lower rate of chlorine excretion which constituted less than half of the sodium excretion. The biochemical blood values of the subjects of the experiment varied prior to the experiment. It is necessary, therefore, to determine the system of normal PH retention by the body. The ratio between sodium and chlorine excretions by the kidney and the rate of ventilation among the three subjects was already mentioned

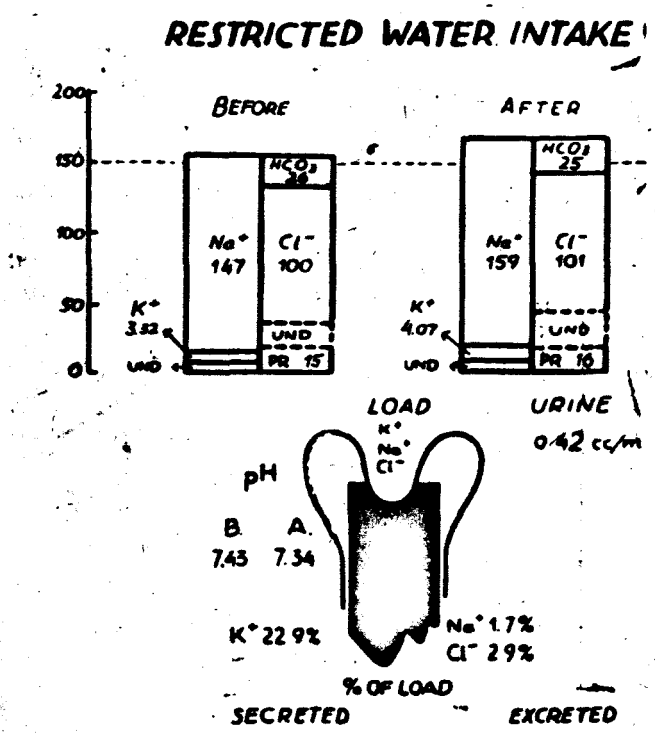


Diagram 6

Sh. M. (diagram 6) walked without drinking. Sh. M. showed no indications of high sodium content in the blood prior to the hike. The sodium content in his blood was found to be at the higher level of the normal, while his potassium content was somewhat lower. The level of the bicarbonates, chlorine and blood proteins were also found to be within the normal range. After the hike, his temperature rose and he showed definite signs of hypernatremia. During the hike, Sh. M. execreted only 0.42 millimeters of urine per second. The rate of ventilation increased (diagram 9) and the PH in the blood during the hike decreased from 7.43 to 7.34.

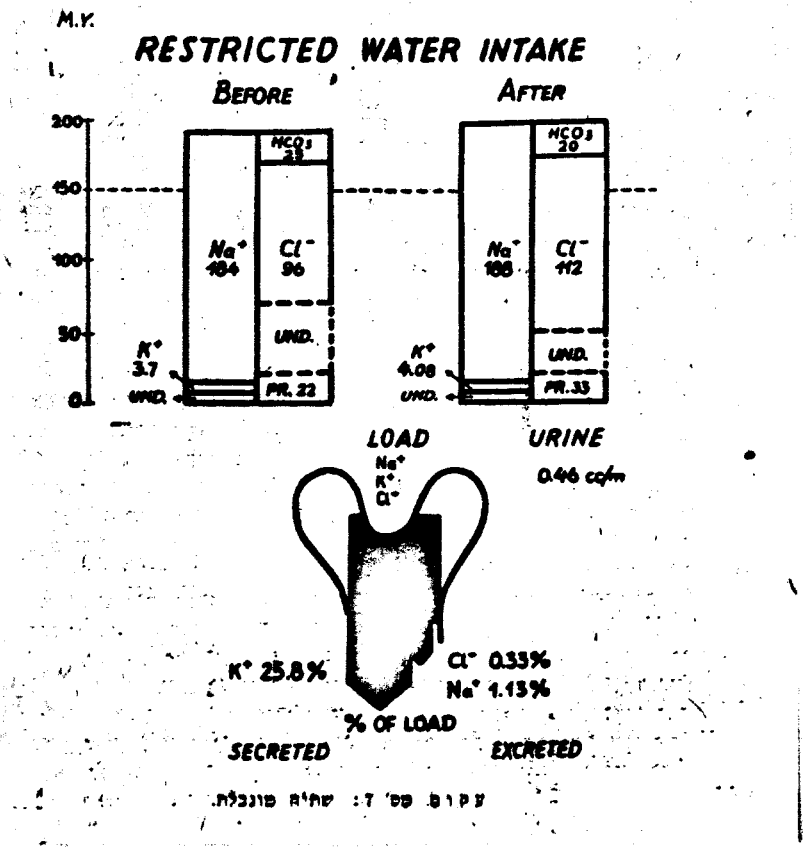


Diagram 7

M. Y. (diagram 7) who walked without drinking showed signs of serious hypernatremic even before the hike. After the completion of the hike, the hypernatremia increased only by 4m Eq/L. The potassium content showed a slight increase and the chlorine also increased by 4m Eq/L. At the same time, the bicarbonate content was slightly smaller and the blood proteins increased from 9.14 to 13.6 gram %. M. Y. excreted 1.13% of the sodium and 0.33% of the chlorine in the urine. The chlorine content of the blood increased and the ventilation which was above normal continued to increase (diagram 9).

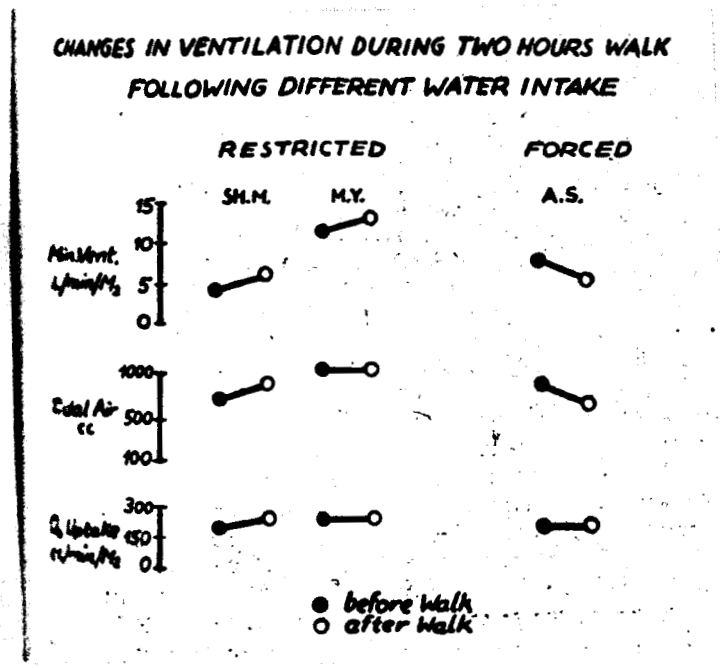


Diagram 9

The experiment with M. Y. reveals the need for further exploration of the problem of arriving at ways and means of determining the exact level of hypernatremia among the residents of the hot regions.

The biochemical changes in the blood and the function of the kidney among the subjects with forced water intake reveal an entirely different pattern.

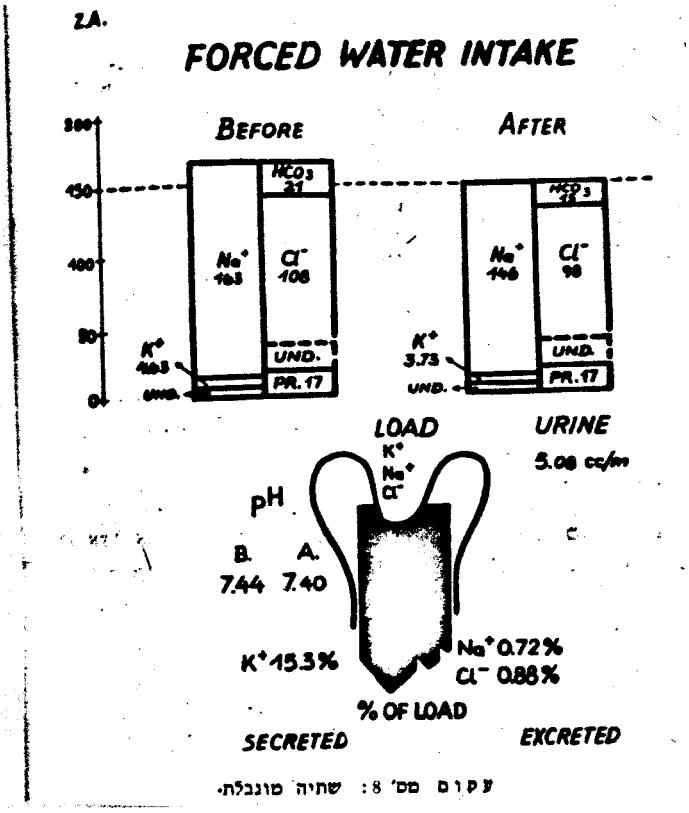


Diagram 8

A. S. (diagram 8) started the experiment with a state of hypernatremia of 163m Eq/L. The bicarbonate content was 21m Eq/L. The chlorine content was somewhat higher than normal while the level of the blood proteins remained normal. Excessive drinking in spite of walking in the heat resulted in the drop of the sodium to 146m Eq/L. The bicarbonates in the blood also decreased and the chlorine level decreased by 10m Eq/L. At the same time, the level of the blood proteins remained steady. A. S. excreted five millimeters of urine per second. The excretion of chlorine was almost equal to the excretion of sodium. The PH remained at the higher level of the normal range while the ventilation became normal.

The A.K.G. of the subjects who developed hypernatremia showed an increase especially in the chest connections, T., however, decreased after excessive drinking. The level of T. was smaller as well as the sodium content of the blood. The above symptoms are quite clear and merit further investigation. (17)

Discussion

At the beginning of the summer, in the hot climate of the Dead Sea region, there are indications that people lose weight and show signs of restlessness and agitation. In the afternoon hours, it is extremely difficult to continue working and the daily consumption of water is between 6 to 10 liters.

Our experiment has shown that even subjects who are accustomed to the arid conditions of the area can develop an excess of sodium in the blood after a two hour hike without water at a speed of six kilometers per hour and a temperature of 42°C.

It has been demonstrated that in spite of the exertion of walking adequate drinking could not only prevent the excess of sodium in the blood but was also capable of correcting such symptoms. This fact has, therefore, shown that the major cause of hypernatremia was not the loss of salt but the loss of water. Kerpel Frenius (19) has demonstrated the veracity of this fact in his experiments with animals and Nodal has done so in his experiments with humans. Our experiment has shown that our subjects revealed no substantial changes in the hematokrit and their blood pressure remained invariably steady.

It is encouraging to note the comparison of changes in the blood volume to the changes in the sodium content of the blood especially among the subjects without water intake in accordance with the formula $Vb_2 = Vb_1 \frac{(Hb)_1}{(Hb)_2}$.

Table 2 Changes in the sodium content and the blood volume during the experiment

Name	Sodium content		Blood volume	
	Before experiment	After experiment	Before experiment	After experiment
M	147	159	4664	4599 (-65)
A	154	162	4672	43 3 (-369
Y	184	188	5696	4631 (-1065)

The subject who started the experiment with normal sodium content of 147m Eq/L increased the sodium content in the blood by 12m Eq/L, while the volume of the blood remained fairly constant. A member of the same group who started the

experiment with a slight hypernatremia of 154m Eq/L increased the sodium in the blood by only 8m Eq/L and decreased the volume of the blood by less than half a liter.

The third member of the group who started the experiment with a serious state of hypernatremia of 184m Eq/L increased the sodium of the blood by only 4m Eq/L in spite of losing more liquids than the other members of the group. His blood volume, however, decreased by one liter.

It is a well-known fact that dilution causes a slight increase in the urea content of the blood due to changes in the texture. These symptoms were shown by the group without water intake. The subjects of this group had the lowest rate of urea clearance and the urea content in the urine was very low (see diagram 5).

The subjects of the group which drank at will excreted five times as much urea as the subjects without water intake. The larger volume of urea can be attributed to the rate of glomerulus distillation and the greater volume of urine excretions.

The comparison of the results of eloctrolyte excretion in the urine draws attention to the following two significant facts:

1. The excretion of chlorine among the subjects without water intake was twice as large as the rate of sodium excretion. In the case, however, of the subjects who drank at will the excretion of chlorine was less than half of the rate of sodium excretion. We may, therefore, assume that the excessive excretion of chlorine is designed to safeguard the PH which, in spite of the exertion, remained normal. This phenomenon also accounts for the discrepancy existing between the rise of sodium and chlorine in the blood.

2. With the rise of dryness, the excretion of sodium in the urine in spite of hypernatremia remains quite low. (23)

The intercellular spacing expanded among the subjects with forced water intake. At the same time, the subjects of this group excreted a large volume of urine and the rate of their sodium excretions was 12 times larger than the excretion of sodium by the subjects without water intake. The excretion of potassium among the subjects of this group was only 1/10 of the sodium excretion. The weight of the urine of only one subject was measured and was found to be 1018 due to the small quantity of urine excretion among the subjects without water intake.

The weight of the urine among the subjects who drank at will ranged between 1021 and 1023. The weight of the urine of the subjects with forced water intake decreased to a level between 1005 to 1001. The above facts indicate that in a hot climate the function of ADH remains undisturbed.

Conclusion

In hot climates, a subject can develop hypernatremia after walking for two hours at a speed of six kilometers per hour and a temperature of 42°C.

Drinking at will does not always prevent the occurrence of hypernatremia. The hypernatremia in the blood was accompanied in such cases by secondary hyperaldosteronism. The subjects who developed hypernatremia excreted little sodium and bigger quantities of chlorine in the urine. This fact accompanied by increased ventilation preserved the level of the PH which although smaller remained at the lower limits.

In a temperature of 42°C forced drinking could prevent and correct the hypernatremia in spite of the exertion of walking; whereas, the subjects without fluid intake complained of fatigue, thirst, dryness of the mouth and restlessness. Those who drank at will complained only of tiredness.

Research work in the area of climatic influences upon men in the hot regions began between 1941 - 1943 by the center of the Sick Fund (Kupat-Cholim) in Tel-Aviv. The acquisition of equipment for this research between 1955 - 1956 was financed by the Ford Foundation. Beginning in the summer of 1957, research in this area was conducted by the Department of Trade Unions of the executive committee of the Histadrut.

The chemical tests were conducted by F. Katz, chemical engineer, M. Lev, S. Zalmonovoka M Sc and S. Zorkowski M Sc (members of the Beilinson Hospital).

Our thanks to Mr. Ory Mona from the Government Meterological Department in Tel-Aviv for the meterological data of the Sodom region.